



Biodiversity Survey of Moths of Fundy National Park:

3. Biodiversity measures in natural habitats of the Fundy Highlands (Acadian Forest Ecoregion)

Douglas Clay and Jane Watts

December, 2000

Report 026

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Report 026

Biodiversity Survey of Moths of Fundy National Park:

**3. Biodiversity measures in natural
habitats of the Fundy Highlands
(Acadian Forest Ecoregion)**

by

Douglas Clay*
PARK ECOLOGIST

and

Jane Watts
RESEARCH ASSISTANT

December, 2000

Fundy National Park, Department of Canadian Heritage
PO Box 40, Alma, New Brunswick
Canada E0A 1B0

* Present address: Regional Science Advisor,
Scientific Research and Experimental Development Section,
Revenue Canada, 220 4th Avenue SE, Calgary, Alberta T2G 0L1

Canadian Cataloguing in Publication Data

Clay, Douglas, 1948-

Biodiversity Survey of Moths of Fundy National Park:

3. Biodiversity measures in natural habitats of the Fundy Highlands
(Acadian Forest Ecoregion)

(Parks Canada - technical report in ecosystem science,

ISSN 1200-3298; report no. 26)

Issued as Part 3. Biodiversity Survey of Moths of Fundy National Park.

Includes an abstract in French.

Includes bibliographic references and an index.

ISBN 0-662-28307-4

Catalogue No. R61-2/19-26-2000E

1. Moths – New Brunswick – Fundy National Park.
2. Moths – Ecology – Greater Fundy Ecosystem – New Brunswick.
3. Lepidoptera – Moths – Forestry – Biodiversity – Fundy National Park (N.B.).

- I. Watts, Jane
- II. Parks Canada. Atlantic Region.
- III. Title.
- IV. Series: Technical reports in Ecosystem Science; no. 26.

QL552.C52 1999 595.78'09715'31 C99-980452-9

Published by authority of the Minister of Canadian Heritage
© Her Majesty the Queen in Right of Canada, represented by
the Chief Executive Officer of Parks Canada, 2000

ISSN 1200-3298; report no. 26

ISBN 0-662-28307-4

Catalogue No. R61-2/19-26-2000E

ACKNOWLEDGEMENTS

This monitoring program of the macromoths was established and funded by Parks Canada to complement the 'forest-pest' monitoring being conducted by the former Forest Insect and Disease Survey (FIDS) of the Canadian Forest Service (CFS) - Atlantic Forestry Center. Unfortunately FIDS ended their long-term monitoring in 1994 with the reorganization of the CFS. We appreciate the work done by the FIDS program from the late 1960s to 1993 and we would like to thank Ed Hurley for leaving their light traps for our continuing use and Georgette Smith for providing the raw data sheets for the FIDS collections from 1984 to 1992.

Field sampling for monitoring programs such as this, requires staff commitment and dedicated work in the office and laboratory to complete the identification and maintain the digital databases. The identifications were done by Jim Edsall, consultant, Moncton, NB and Dr. A.W. Thomas, Atlantic Forestry Center, Fredericton, with some sorting assistance by Shirley Butland and other Parks Canada Resource Conservation staff. Resource Conservation warden staff emptied and pre-sorted the Alma trap throughout the study, Betty Betts keypunched the data from a wide variety of data coding forms, and Shirley Butland assisted in the data collating and editing.

Dr. A. (Tony) W. Thomas and Prof. Rob Longair, Biology Department, University of Calgary provided helpful criticism of an earlier version of this manuscript, their suggestions and guidance are greatly appreciated.

Correct citation for this publication:

Clay, D. and J. Watts. 1999. Biodiversity survey of moths of Fundy National Park: 3. Biodiversity measures in natural habitats of the Fundy Highlands (Acadian Forest Ecoregion). Pks. Can. Tech. Rep. Eco. Sci., No. 026, pp. v + 21.

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ABSTRACT

Clay, D. and J. Watts. 1999. Biodiversity survey of moths of Fundy National Park: 3. Biodiversity measures in natural habitats of the Fundy Highlands (Acadian Forest Ecoregion). Pks. Can. Tech. Rep. Eco. Sci., Tech. Rep. No. 026, pp. 21.

This report is an introduction to the community diversity of the moth fauna of Fundy National Park and its greater ecosystem. We describe the community structure and diversity as observed over a four year period (1993 to 1996). A list of the 634 moth species identified, though not provided here, is available in Part I of this report series). The present data are analyzed to develop an estimate of baseline values of community diversity and similarity. The log-series α diversity index ranges from 70 to 90 for the mixed-wood coastal Acadian Forest ecoregion of southern New Brunswick. Within site similarity indices (Morista-Horn) are about 0.9, while between site is about 0.5 and between year (within site) is about 0.6.

Season and site similarity are assessed for a coastal and inland site in the red spruce/ balsam fir forests of Atlantic Canada. The flying season in this region of eastern North America ranges from 195 to 237 days (early April to mid November). Habitat differences (vegetative community) appear to have a greater effect on similarity than year to year (seasonal) differences. Highest diversity was found in July with about 55% of all species being considered rare. Duration, period of sampling, and anomalous population outbreaks of individual species were found to affect the apparent diversity and must be taken into account when comparing studies carried out by various methods.

RÉSUMÉ

Clay, D. and J. Watts. 1999. Biodiversity survey of moths of Fundy National Park: 3. Biodiversity measures in natural habitats of the Fundy Highlands (Acadian Forest Ecoregion). Pks. Can. Tech. Rep. Eco. Sci., Tech. Rep. No. 026, pp. 21.

Cet état est une introduction à la diversité de la communauté de la faune des papillon nocturnes du parc national de Fundy et de son plus grand écosystème. Nous décrivons la structure et la diversité de la communauté comme observée sur une période de quatre ans (1993 à 1996). Une liste des 634 espèces des papillon nocturnes identifiées (pas fournie ici), est disponible dans la partie I de cette série d'état. Les données actuelles sont analysées pour développer une évaluation des valeurs de ligne de base de diversité et de similitude de la communauté. La logarithme-série α un incrément de diversité s'étend de 70 à 90 pour l'ecoregion Acadien côtier de forêt de mélanger-bois du sud Nouveau Brunswick. Dans les incréments de similitude de site (Morista-Horn) sont environ 0,9, alors qu'entre le site sont environ 0,5 et entre l'année (dans le site) a lieu environ 0,6.

La saison et la similitude de site sont évaluées pour un site côtier et intérieur dans les forêts épinette rouges / de sapins baume du Canada atlantique. La saison de vol dans cette région de l'Amérique du Nord orientale s'étend de 195 à 237 jours (début avril à mi novembre). Les différences d'habitat (la communauté végétative) semblent avoir un plus grand effet sur la similitude que l'année aux différences (saisonnières) d'année. La diversité la plus élevée a été trouvée en juillet avec environ 55% de toutes les espèces étant considérées rares. La durée, la période du prélèvement, et les manifestations anormales de population de différentes espèces se sont avérées pour affecter la diversité apparente et doivent être prises en considération en comparant des études effectuées par de diverses méthodes.

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INTRODUCTION

The *Guiding Principles and Operational Policies* of Parks Canada state that 'protecting ecological integrity ... take[s] precedence ... ' over other activities (Anon, 1994). Biodiversity is often used in attempting to define ecological integrity and higher values of diversity are frequently seen as indicators of well being (Magurran, 1988). Some authors (Ives et al., 1999) have argued that other factors are more important.

Changes in species diversity may be indicative of stressed ecosystems. We believe that moths could be used as a monitoring tool to detect and rank changes in biodiversity that may result from habitat loss. Moths are useful indicators because they are biologically important in the Acadian forest ecosystem and they can be sampled relatively easily with a standardized procedure. As a major converter of plant biomass to animal fats and proteins, Lepidoptera drive the flow of energy that allows for the high biodiversity seen in forest ecosystems (Clay, 1999). New (1997) suggested that Lepidoptera provide an effective 'umbrella group' for biodiversity conservation. This is due to the strong specific associations which often exist between Lepidoptera and the

plants they require for food and reproduction.

In order to detect change, a baseline inventory of species occurring in the park, their seasonal distribution and relative abundance must be established. High temporal fluctuations can mask real change, thus long term monitoring studies are required to overcome this phenomenon. The Canadian Forest Service (CFS) conducted 'forest insect pest' monitoring for 'target species' ¹ from the late 1960's to 1993. Staff of Fundy National Park (Fundy NP) extended this program in 1993 to collect and identify all species of macromoths (see Thomas *et al.*, 1998). This detailed survey was conducted between 1993 and 1996 (with some associated sampling in 1997), and concentrated primarily on the larger species of moths (all macrolepidoptera and larger species of microlepidoptera). A species checklist of 634 species found in Fundy NP and its adjacent area, and their flight periods, is available in the first part of this series (Thomas *et al.*, *ibid*). Although the macrolepidoptera were of primary interest it is expected that the species richness within the larger moths is likely to be mirrored in the smaller moths, the microlepidoptera in the same habitats.

The overall objectives for this investigation were to characterize:

- ◆ the moth fauna of Fundy NP and its adjacent area in terms of species present;

¹ The targets for this national program included 72 'species' (or genera) that were considered significant forest pests. Not all of these 'species' occur in Atlantic Canada and between 1984 and 1992 only 54 of these 'species' were recorded in Fundy NP (see Appendix I).

- ♦ the abundance of species and individuals;
- ♦ the pattern of species emergence throughout the year; and
- ♦ the baseline diversity within different habitats.

A secondary objective was to determine the natural variation between years and sites in order to determine a suitable protocol for measuring diversity, i.e., sub-sampling within a year or between years?

Solis and Pogue (1999) demonstrated that site specific data collection and analysis were a prerequisite to thorough understanding of regional diversity patterns. This report provides an overview of the macromoth community in two locations in Fundy NP over a 4 year period. It will serve as reference material for other detailed analyses of moth species diversity in forested habitats throughout the park and the Greater Fundy Ecosystem (GFE). It is based on data from a coastal site near the village of Alma, NB at the east gate of Fundy NP and a more inland site near Wolfe Lake at the west entrance to the park (Figure 1).

METHODS

Clay (1999) provides details of the site descriptions, vegetative communities, and sampling methodology. Only a brief overview will be provided here.

1.0 Sampling equipment

This monitoring was originally designed to continue and expand upon the work being undertaken by the CFS. Unfortunately, one year into our co-operative program, the CFS was re-

organized and their long-term pest monitoring program ended. To be compatible with the existing data we chose to use an older-style light-trap which used a 120 V 15-watt 'cool white' fluorescent light source. Two of these traps were used in the long-term monitoring program of the park.

2.0 Sampling methodology

Our sampling methodology involved operating a light-trap at each of two sites between March and December (1993 to 1996). An effort was made to operate the traps at both sites on the same nights. For various reasons this was occasionally not possible.

In 1993, the traps were started in early May, and ran until November. Monitoring was terminated following seven consecutive nights with zero catch. In other years, the traps were started on April 1, and also ran until November. The traps were operated and emptied daily whenever possible. The traps were on mains power and always on, thus the sampling intervals were dusk to dawn. The catches were sorted and the Lepidoptera stored dry and frozen until they could be processed.

3.0 Data management

3.1 Identification and nomenclature

An attempt was made to identify every specimen to the species level in all 10 families of macrolepidoptera, and in five families of larger microlepidoptera found in New Brunswick (see Thomas *et al.*, 1998). Mr. J. Edsall did the identification in 1993, 1994, and 1995 and in 1996 it was done by Dr. A.W. Thomas.

Most specimens could be identified using wing colour and pattern. However, some specimens were in such poor condition (due to the large numbers of moths caught and the ravages of beetles and slugs that sometimes entered the traps) that genitalia dissections were required to ensure correct identification. Such dissections were only done in 1996. For some groups with a high degree of external similarity, e.g., the genus *Eupithecia* in the family Geometridae, all identifications should be made from genitalia dissections. Thus species richness within this genus and certain other genera could be affected, particularly when comparing 1996 to earlier years.

The sequence of taxa follows Hodges *et al.* (1983) checklist and the species identification numbers (used in other reports) refer to their check list numbers.

To simplify analysis and presentation of data, dates are often represented in terms of Julian days of the year (January 1 being 1 and April 1 being 90, etc.) and Julian weeks (January 1 to 7 being week 1, and April 1 to 7 being week 13, etc.) (see Appendix II).

Voucher specimens from this monitoring program are housed in the New Brunswick Museum in Saint John and in the headquarters building at Fundy NP. In addition there is an extensive collection of moths and genitalia preparations held by the Dr. A.W. Thomas at the Atlantic Forestry Center in Fredericton, NB.

4.0 Analysis

There are two basic approaches that can be followed for analyzing insect

monitoring investigations. The first assesses the biology and behaviour of a species or group of species. Such species are usually economically important and often considered pests (see Appendix I), e.g. spruce budworm (*Choristoneura fumiferana*). The second assesses the community structure and species diversity with or without regard for which species comprise the community. We have followed the latter approach for the analysis of the data from our four year community monitoring investigation.

Biodiversity measures such as those reviewed by Magurran (1988) are convenient methods for comparing communities, either through time or space. Communities tend to be made up of many rare species and a few common ones. This characteristic of species abundance models has been used to assess the 'naturalness' of a community. Some taxa, eg. ground-beetles (Carabids), appear not to fit a smooth distribution (Niemela, 1993). However the macromoths have been shown to fit a log-series curve - often referred to as Williams's alpha (α) (Spellerberg, 1991).

Fisher *et al.* (1943) developed the original log-series α index and Williams (1964) suggested that in an ideal habitat the population would fit the log-series, diverging as the habitat changed (lost integrity). The degree of divergence through such loss of ecological integrity would be dependent upon the species or community in question. This may explain why the carabid community (above) does not fit the expected distribution pattern in an 'old growth' forest setting - this habitat may not be ideal for these ground dwelling beetles.

Diversity of natural habitats

In our case this will not be an issue as no obvious change of habitat occurred in the neighborhood of our two sample sites over the study period. We are only assessing annual variation in a community of light-trapped macromoths.

We have used the log-series α index to describe the sampled communities used to develop this baseline index. In addition we have calculated the Shannon index (H'), the Shannon evenness index (E), and the Simpson index (D). These indices are often criticized for being sensitive to rare species (Shannon) or common species (Simpson). These weaknesses were used as an aid to investigate and interpret variation in properties of these moth communities.

Data points estimated from limited sample sizes (≤ 3 species or ≤ 2 abundance classes (for α index)) were dropped from any calculations as were any weeks resulting in a significant χ^2 at $P < 0.05$.

Similarity (or its inverse, change) between habitats (sites) is often referred to as β diversity (Magurran, 1988). Similarity indices have been used to assess differences in habitat as well as changes in the same community over time.

In our analysis we have used two similarity indices to measure habitat effects on diversity. The Sorenson quantitative index is somewhat sensitive to species richness while the Morista-Horn index is less affected by species richness and sample size (Spellerberg, 1991).

To interpret the similarity between two sites or time periods it is necessary to

understand the natural variation in the community and the replicate sampling equipment. Taking samples as close together in time and space as possible in order to develop a reference similarity index for what are considered replicate samples usually accomplishes this.

Replicate samples were not available from this monitoring program. Thus, to develop a reference similarity index for each of our two locations a comparison was made between the even and odd sampling days at each site in each of the four survey years.

We have arbitrarily defined rare and abundant species in this study in the following manner. Rare species are those with three or less individuals caught at the site for the year. Abundant species are those more common species whose cumulative total numbers (all species) comprise more than 5% of the total annual sample of all individuals.

RESULTS AND DISCUSSION

Community structure

The mean date of first capture for Alma was in early April (9th). The final capture date for the season for that site occurred in mid to late November (19th). For Wolfe Lake, the first date of capture was approximately a week later than in Alma (April 15), with the final capture date occurring approximately a week earlier (November 13) (Table 1).

The number of species caught each year ranged from 244 to 339. In all three

comparable² years of sampling, Wolfe Lake had more species, although in 1995 the number of species for both sites was almost equal (Table 1). The number of individuals caught per year ranged between 1955 and 4132, the Alma site had a higher number of individuals caught in two of the three years. A study by Dirks in 1937 (Preston, 1948) in Orono, Maine used similar collecting equipment and sampled a similar though milder environment. In four years he sampled 349 species of an estimated potential population containing 410 species.

Community structure, or more specifically species composition, for both sites was similar with 26 to 33% of all species occurring only once in a year and 49 to 58% of all species being represented by 3 or fewer individuals (Table 1), considered rare for that site in that year.

The patterns of species abundance within the macromoth communities were similar at Alma and Wolfe Lake during the four year survey period. The species abundance curves (Figures 2 and 3) demonstrate that the majority of species are represented by only a few individuals. On the other hand, a few species are represented by a large number of individuals, generally about 5% of the species in the community were represented by more than 25 individuals captured during a year. We considered these species as abundant at that site in that year. The macromoth community structure, defined by the species abundance curves, found at the Alma and Wolfe Lake sites appears to be

consistent with that found in other studies (Williams, 1964; Lewis and Taylor, 1967; Thomas, 1996), and typical of relatively undisturbed, or stable habitats.

Community diversity

Annual diversity, log-series α , measured at the two sites ranged from 70 to 90, and for the Shannon index from 4.1 to 4.7 (Table 1). The Wolfe Lake site showed significantly higher moth diversity than the Alma site ($T = 4.97$; $df = 4$) (Table 1) as measured by the Shannon index while the α community index indicated no significant difference between sites ($T = 2.48$; $df = 4$). This implies there was a significant difference in the number of rare species between the two sites with the Wolfe Lake site having more species with smaller total catches and many more single and double occurrences (Table 1).

Monthly diversity (α) exhibited a seasonal pattern for both sites with the highest value occurring in mid-summer. The diversity found at Alma was highest in July in 1994 and 1996 and in August in 1993 and 1995 (Figure 4). At Wolfe Lake the greatest diversity occurred in July in all four years (Figure 5), although in 1995 June and July were similar in value.

The monthly log-series index for both Alma and Wolfe Lake demonstrated a bell-shaped curve during the survey period. Moth diversity at Wolfe Lake peaked earlier than in Alma each year and sharply decreased in August (Figure 5). The earlier peak season at Wolfe Lake could be due to differences in

² See Table 1 footnote for explanation of why 1993 was omitted from these calculations.

climate. Spring (last snow on the ground to first leaf-out) comes to Wolfe Lake later than Alma, however, once it does arrive, the temperature increases more rapidly than at Alma and soon surpasses the coastal site.

The Shannon index indicated a similar pattern in species richness between years at each location. At Alma, the highest species diversity occurred during June, July and August, with a sharp decline in the number of species occurring in September (Figure 4). At Wolfe Lake, the highest species diversity occurred in June and July, with a more gradual decline in the number of species occurring in August (Figure 5).

Moth community diversity was also calculated from data aggregated on a weekly basis. The seasonal pattern was more variable with this shorter sample period. Soetaert and Heip (1990) assessed sample size requirements for highly diverse marine communities, and for four different indices found that minimum sample sizes of 100 to 500 individuals were required to give 90% precision. This indicates that the weekly data at the beginning and end of the season (with lower sample sizes) will tend to have lower precision than mid-season or monthly data (with higher sample sizes).

Weekly diversity exhibits greater variation than monthly data and generally lower values. Both sites have a bell shaped curve that has its peak spanning a four to six week period. Alma has the greatest diversity occurring between weeks 26 through 31 (June 28 to August 7) (Figure 6). The Wolfe Lake site reaches its peak one to two weeks

earlier than the Alma site, between weeks 25 and 29 (June 21 - July 24) with less interannual variation than the Alma site (Figure 7). The greater variability and extended period of high diversity of the Alma site appears to be a defining characteristic differentiating these sites.

The data from the Alma site indicate the period prior to weeks 19 to 20 exhibits a declining trend in diversity in 1994, 1995, and less so in 1996. This is not applicable to 1993 as the trap was not operating prior to week 18. The same situation does not appear to occur at Wolfe Lake. This may be due to climatic factors where Alma has a more variable spring with early mild temperatures interspersed with periods of cold weather. Wolfe Lake has a later spring with more stable increasing temperatures.

Season and site similarity

The two similarity indices used in this analysis (within site and year) for the Alma and Wolfe Lake sites were variable over the four years of the monitoring program (Table 2a). The most divergent value occurred in Alma in 1993. The rank order of similarity indices over the four years was the same for both sites, possibly indicating a seasonal (weather) link. Wolfe Lake had the higher mean similarity index of the two sites.

The four year mean Sorenson reference index (sensitive to species richness) is nearly identical in both sites (Table 2a). One reason for the relatively low values of what should be nearly equal samples is the high number of rare species (≤ 3 individuals) (Table 1). At least 30% and

potentially closer to 40% of all species will be absent in either the odd or even day samples. Such an artifact in any data must be taken into account.

The low values for the 1993 similarity indices for Alma requires some explanation. The irregular manner of assessing similarity used in this investigation leads to concern regarding the number of singular occurring species that would result in that species being absent in one of the samples. To investigate the possible impact this may have, we tested the lowest values of the similarity indices (Alma 1993) and the highest (Wolfe Lake 1995) by removing all species that were absent from one of the two samples. This editing of the data increased the Morista-Horn index by about 2% for the Alma 1993 data and <1% for the Wolfe Lake 1995 data; the Sorenson index increased about 9% and 5% respectively. As the rare species appeared not to be responsible for the low values, the daily data were reviewed for possible anomalies. On July 13, 189 eastern tent caterpillars (*Malacosoma americanum*, (F.)) and 337 forest tent caterpillars (*Malacosoma disstria*, Hbn.) were captured in the Alma trap. Only 12 other individual *Malacosoma* sp. were caught at Alma in 1993. The Wolfe Lake site had two days of larger catches of *Malacosoma* sp. in 1993, however, they were both less than 40 individuals and they occurred on two different days. When the two records are removed from the 1993 Alma dataset the Morista-Horn index increases from 0.442 to 0.868 and the Sorenson index increases from 0.550 to 0.677, both values fitting well within the limits observed for the other sites and years. A similar, though less pronounced effect with these tent caterpillars

occurred in 1994 at Alma, however by 1995 their numbers were down with no single days of large catches. The potential influence of species that can have population explosions must be accounted for in any such analyses. This shows a potential weakness of these indices, however, using several indices together can aid in the interpretation of such variation.

The mean four year reference Morista-Horn within site index was 0.76 and 0.88 for the Alma and Wolfe Lake sites respectively while the mean 4 year between site index was 0.52. In 1993 the between site similarity index was greater than the within site similarity. In the other three years, the between site similarity was less than the reference within site similarity by 0.20 to 0.55 (Tables 2a, 2b).

The between year within site similarity was greater than the between site within year similarity (Tables 2b, 2c). This implies that habitat differences (probably vegetative communities) between the coastal and inland zones (approximately 20 km separation) of Fundy NP provide greater influence on the composition of the moth community than the annual (climate) differences in either zone.

CONCLUSION

The macromoth community structure, measured by the α index, varies seasonally with the highest diversity occurring in July. Few species are abundant and about 55% can be considered rare (≤ 3 individuals in a season of sampling).

Aggregating the data on a weekly or monthly basis provides a similar diversity, as measured by the Shannon index, during the richest (in terms of species) period of the summer. These weekly and monthly values compare closely with those from the entire flying season. In contrast, the log-series exhibits a progressive decline in diversity as the sampling period is reduced (Table 1). Thus weekly diversity, even during the richest period of summer, is less than the monthly diversity, which is less than the annual value. This is an important consideration when comparing data between studies or when designing a monitoring program. It will be necessary to compare similar seasonal periods with comparable duration of sampling and sampling efficiency (equipment type).

Smaller sample sizes during early and late season sampling and short sample periods increase the natural variability. This may be due to the inherent variability in weather over the short term and the sensitivity of flying insects to such climatic factors.

The similarity indices are sensitive to large catches of a species, especially over a short period. Species such as tent caterpillars and spruce budworm exhibit cyclic population explosions that can result in great shifts in diversity indices. These species also have devastating effects on the forest habitat. Though natural, they mimic anthropogenic factors that result in a loss of ecological integrity. Thus it appears monitoring macromoth community composition could provide a measure of community shifts and habitat loss and/or alteration.

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Diversity of natural habitats

Table 1: Summary of the catch statistics and the diversity found during four years of macromoth monitoring at climate station sites near Alma and Wolfe Lake, Fundy National Park.

	Moth flight activity (First catch) (Last catch)	Flight Season *	No. of Species	No. of Moths	No. Species with 1/2/3 moths *	Shannon diversity (season)	Alpha diversity (season)	Alpha diversity weekly*monthly (highest)
Alma								
1993	May 2	Nov 29	263	2766	88/33/24	4.2	71.4	30/43.6
1994	Apr 4	Nov 27	280	3700	73/44/26	4.1	70.3	40/51.8
1995	Apr 13	Nov 11	299	3996	79/41/32	4.3	74.8	35/49.7
1996	Apr 11	Nov 18	290	3238	80/38/26	4.4	77.5	40/53.3
meantstd	(93-96)	220 ± 12	283 ± 15	3425 ± 539		4.3 ± 0.1	73.5 ± 3.3	
meantstd	(94-96)	223 ± 13	290 ± 10	3645 ± 382		4.3 ± 0.2	74.2 ± 3.6	
Wolfe Lake *								
1993 *	May 11	Nov 22	244	1955	78/42/23	4.6	73.6	40/41.1
1994	Apr 10	Nov 15	339	4132	102/55/19	4.7	87.5	35/56.9
1995	Apr 16	Nov 15	300	3629	79/40/29	4.7	77.6	40/47.3
1996	Apr 18	Nov 10	302	2459	93/51/27	4.7	90.5	35/52.7
meantstd	(93-96)	208 ± 10	296 ± 39	3044 ± 1009		4.7 ± 0.1	82.3 ± 8.0	
meantstd	(94-96)	213 ± 7	314 ± 22	3407 ± 858		4.7 ± 0.0	85.2 ± 6.8	

* The flight (or sampling) season is the number of days between the first and last recorded catch, the length of time the light-trap was run will be longer (see text for how end of season was identified), e.g. in 1994 the site at Wolfe Lake had a season of 219 days while the light trap ran for 235 days - Apr. 1 to Nov. 22.

* Number of species of moths in that season having only 1, 2, or 3 individuals caught

* Due to the variability caused by the smaller sample size in weekly data, the value selected was not the highest but rather the top of a bell shaped curve fitted to the data by eye.

* The light trap for the Wolfe Lake monitoring site began operation on May 11, 1993, 11 days later than the trap in Alma. Thus 1993 data from Wolfe Lake is not directly comparable with the other years at Wolfe Lake nor with the 1993 data from Alma. The 1993 values from Wolfe Lake were omitted from calculations assuming equal sampling effort. In all other years the traps at both sites were started on Apr. 1.

Diversity of natural habitats

Table 2a. Reference similarity indices developed for the macro moth monitoring sites at Alma and Wolfe Lake, Fundy NP. These (within site and year) indices were calculated from a comparison of the even and odd day samples from each site in each year.

Year	Alma (No. Species)			Wolfe Lake (No. Species)		
	1 per trap / total *	Sorenson	Morista-Horn	1 per trap / total	Sorenson	Morista-Horn
1993	129/263	0.550 (.677*)	0.442 (.868*)	115/244	0.602 (.618*)	0.778 (.812*)
1994	111/280	0.661	0.754	157/339	0.694	0.851
1995	118/299	0.785	0.942	109/300	0.784	0.955
1996	122/290	0.734	0.882	133/302	0.697	0.942
mean		0.68 ± 0.10	0.76 ± 0.22		0.69 ± 0.07	0.88 ± 0.08
mean		0.71 ± 0.06	0.86 ± 0.08		0.70 ± 0.07	0.89 ± 0.07

Table 2b. Between site similarity indices comparing samples from the Alma and Wolfe Lake sites during the years 1993 to 1996.

Year	Alma (No. Species)		Wolfe Lake (No. Species)	
	1 per year / total *	Sorenson	1 per trap / total *	Sorenson
1993	157/328	0.455	0.563	
1994	205/413	0.399	0.255	
1995	157/378	0.531	0.559	
1996	170/382	0.481	0.692	
mean		0.47 ± 0.06	0.52 ± 0.19	

Table 2c. Between year similarity indices comparing samples from consecutive years for the Alma and Wolfe Lake sites respectively.

Year	Alma (No. Species)			Wolfe Lake (No. Species)		
	1 per trap / total *	Sorenson	Morista-Horn	1 per trap / total *	Sorenson	Morista-Horn
1993/94	183/363	0.531	0.763	185/385	0.442	0.514
1994/95	197/389	0.468	0.481	169/405	0.544	0.469
1995/96	195/393	0.515	0.548	183/393	0.555	0.776
mean		0.51 ± 0.03	0.60 ± 0.15		0.52 ± 0.06	0.59 ± 0.17

* The number of species absent from one of the two simulated samples (traps or years) and the total number of species in the two samples (total catch for that site/year).

* Corrected values with species which exhibit cyclic population explosions (ie. tent caterpillars) removed

Appendix I.

Fifty four species (or genus) of moths, captured in the Alma, Fundy NP white-light trap between 1984 and 1992 inclusive. These moths were considered significant pests by the FIDS of CFS. These data are ordered by total numbers of individuals caught during the 9 years of survey. (These data were made available by Ed Hurley and Georgette Smith of the CFS in Fredericton.)

SCIENTIFIC NAME	SUCCESSFUL NIGHTS	No. OF MOTHS	FIRST / LAST CAPTURES	DAYS
<i>Choristoneura fumiferana</i> (Clem.)	62	4233	20/Jun-11/Aug	53
<i>Lambdina fiscellaria</i> (Gn.)	152	480	27/Aug-25/Oct	60
<i>Operophetra</i> sp. ¹	56	218	10/Sep-24/Nov	76
<i>Malacosoma disstria</i> Hbn.	67	207	5/Jul- 3/Sep	61
<i>Lophocampa maculata</i> Harr.	39	185	11/Jun-29/Jul	49
<i>Nadata gibbosa</i> (J.E. Smith)	64	144	11/Jun-29/Aug	80
<i>Dioryctria reniculoides</i> Mutuura & Mun.	45	140	3/Jul-29/Aug	58
<i>Alsophila pometaria</i> (Harr.)	35	129	9/Sep-17/Nov	70
<i>Choristoneura rosaceana</i> (Harr.)	43	118	5/Jul-19/Aug	46
<i>Feralia</i> sp. ²	31	98	1/May-18/Jun	49
<i>Itame pustularia</i> (Gn.)	36	90	8/Jul-28/Aug	52
<i>Choristoneura conflictana</i> (Wlk.)	5	78	4/Jul-14/Jul	11
<i>Caripeta divisata</i> Wlk.	41	76	4/Jul-27/Aug	55
<i>Ectropis crepuscularia</i> (D. & S.)	31	75	15/May-31/Jul	78
<i>Campaea perlata</i> (Gn.)	26	50	4/Jul-16/Aug	44
<i>Ennomos magnaria</i> Gn.	31	50	27/Aug-11/Oct	46
<i>Antheraea polyphemus</i> (Cram.)	26	47	2/Jun-31/Jul	60
<i>Heterocampa guttivitta</i> (Wlk.)	26	45	30/May- 8/Aug	71
<i>Orthosia hibisci</i> (Gn.)	25	43	30/Apr- 1/Jun	33
<i>Epirrata autumnata</i> henshawi (Swett)	23	40	3/Oct-30/Oct	28
<i>Orgyia leucostigma plagiata</i> (Wlk.)	27	39	29/Aug-10/Oct	43
<i>Cladara limitaria</i> (Wlk.)	11	29	1/May-24/Jun	55
<i>Hyphantria cunea</i> (Drury)	16	25	11/Jun-31/Jul	51
<i>Smerinthus cerisyi</i> Kby.	19	24	4/Jun-17/Aug	75
<i>Heterocampa</i> sp. ³	14	23	2/Jun-27/Aug	87
<i>Dryocampa rubicunda</i> (F.)	12	23	2/Jun- 5/Jul	34
<i>Leucoma salicis</i> (L.)	14	22	4/Jul- 8/Aug	36
<i>Orthosia revicta</i> (Morr.)	12	22	1/May-30/Jun	61
<i>Noctua pronuba</i> (L.)	20	22	13/Aug-25/Sep	44
<i>Spilosoma virginica</i> (F.)	9	21	20/Jun- 5/Jul	16

¹ The 2 species of *Operophetra* found in near equal numbers during intensive surveys between 1993 and 1997 (Thomas *et al.*, 1998) were *O. brumata* (L.) and *O. bruceata* (Hulst.).

² Of the 2 *Feralia* species, in FNP, *F. comstocki* (Grt.) was 30 times more common than *F. jocosus* (Gn. Grt.) during the 1993 to 1997 surveys (Thomas *et al.*, 1998).

³ There were 3 species of *Heterocampa* found during the 1993 to 1997 surveys (Thomas *et al.*, 1998); *H. guttivitta* (Wlk.), *H. biundata* Wlk., and *H. umbrata* Wlk. in a ratio of 10:6:1 respectively, all relatively common.

Diversity of natural habitats

Appendix I. con't

SCIENTIFIC NAME	SUCCESSFUL NIGHTS	No. OF MOTHS	FIRST / LAST CAPTURES	DAYS
<i>Crocigrapha normani</i> (Grt.)	11	19	13/May-12/Jun	31
<i>Archips rosana</i> (L.)	12	17	30/Jun- 7/Aug	39
<i>Meroptera pravella</i> (Grt.)	7	14	31/Jun-21/Jul	21
<i>Sparganothis acerivorana</i> MacKay	11	14	13/Jul- 4/Aug	23
<i>Sparganothis reticulatana</i> (Clem.)	8	13	18/Aug- 5/Sep	19
<i>Malacosoma americanum</i> (F.)	9	12	8/Jul-27/Jul	20
<i>Croesia semipurpurana</i> (Kft.)	4	8	20/Jul-23/Jul	4
<i>Orthotaenia undulana</i> (D. & S.)	6	7	27/Jun-19/Jul	23
<i>Pseudosciaphilia duplex</i> (Wlsm.)	6	7	21/Jun-10/Jul	20
<i>Pachysphinx modesta</i> (Harr.)	5	7	15/Jun-11/Jul	27
<i>Prochoerodes transversata</i> (Drury)	4	6	13/Aug- 5/Sep	24
<i>Phigalia titea</i> (Cram.)	3	6	30/May-10/Jun	12
<i>Egira dolosa</i> (Grt.)	5	6	15/May- 2/Jun	19
<i>Ipimorpha pleonectusa</i> Grt.	5	5	21/Aug- 4/Sep	15
<i>Archips cerasivorana</i> (Fitch)	3	5	27/Jul-29/Aug	34
<i>Pheosia rimosa</i> Pack.	4	4	18/Jun- 2/Aug	46
<i>Nematocampa resistaria</i> (H.-S.)	3	4	31/Jul- 9/Sep	41
<i>Pseudexentera oregonana</i> (Wlsm.)	2	2	15/Jul-30/Jul	16
<i>Archips argyrospila</i> (Wlk.)	2	2	30/Jun-10/Aug	42
<i>Thera juniperata</i> (L.)	2	2	6/Oct- 5/Nov	31
<i>Zeiraphera improbana</i> (Wlk.)	1	1	4/Sep- 4/Sep	1
<i>Erannis tiliaria</i> (Harr.)	1	1	28/Sep-28/Sep	1
<i>Symmerista</i> sp. ⁴	1	1	2/Jul- 2/Jul	1
<i>Cingilia catenaria</i> (Drury)	1	1	31/Sep-31/Sep	1
Total Number of individuals :		6960		
Total number of 'species' :		54		
Total number of years surveyed:		9		

⁴ The 3 species of *Symmerista* found during the 1993 to 1997 surveys (Thomas *et al.*, 1998) were all relatively rare; they were *S. leucitys* Franc., *S. canicosta* Franc., and *S. albifrons* (J.E. Smith).

Appendix II.

The use of Julian days and Julian weeks instead of actual dates has been followed throughout this study to simplify analysis and visual display. The analysis of annual records, e.g. of light trap catches, can be simplified if the numbered "weeks" contain the same dates in successive years. This can easily be obtained by dropping the dates February 29 and December 31 from the calendar (after Lewis and Taylor, 1967). The weeks then become, by number, as follows:

Julian Week No.	Dates	Julian Week No.	Dates
1	Jan. 1 -Jan. 7	27	July 2 -July 8
2	Jan. 8 -Jan. 14	28	July 9 -July 15
3	Jan. 15 -Jan. 21	29	July 16-July 22
4	Jan. 22 -Jan. 28	30	July 23-July 29
5	Jan. 29-Feb. 4	31	July 30-Aug. 5
6	Feb. 5 -Feb. 11	32	Aug. 6-Aug. 12
7	Feb. 12-Feb. 18	33	Aug. 13-Aug. 19
8	Feb. 19-Feb. 25	34	Aug. 20-Aug. 26
9	Feb. 26-Mar. 4	35	Aug. 27-Sept. 2
10	Mar. 5-Mar. 11	36	Sept. 3-Sept. 9
11	Mar. 12-Mar. 18	37	Sept. 10-Sept. 16
12	Mar. 19-Mar. 25	38	Sept. 17-Sept. 23
13	Mar. 26-Apr. 1	39	Sept. 24-Sept. 30
14	Apr. 2 -Apr. 8	40	Oct. 1 -Oct. 7
15	Apr. 9-Apr. 15	41	Oct. 8-Oct. 14
16	Apr. 16-Apr. 22	42	Oct. 15-Oct. 21
17	Apr. 23-Apr. 29	43	Oct. 22-Oct. 28
18	Apr. 30-May 6	44	Oct. 29-Nov. 4
19	May 7-May 13	45	Nov. 5-Nov. 11
20	May 14-May 20	46	Nov. 12-Nov. 18
21	May 21-May 27	47	Nov. 19-Nov. 25
22	May 28-June 3	48	Nov. 26-Dec. 2
23	June 4-June 10	49	Dec. 3-Dec. 9
24	June 11-June 17	50	Dec. 10-Dec. 16
25	June 18-June 24	51	Dec. 17-Dec. 23
26	June 25-July 1	52	Dec. 24-Dec. 30

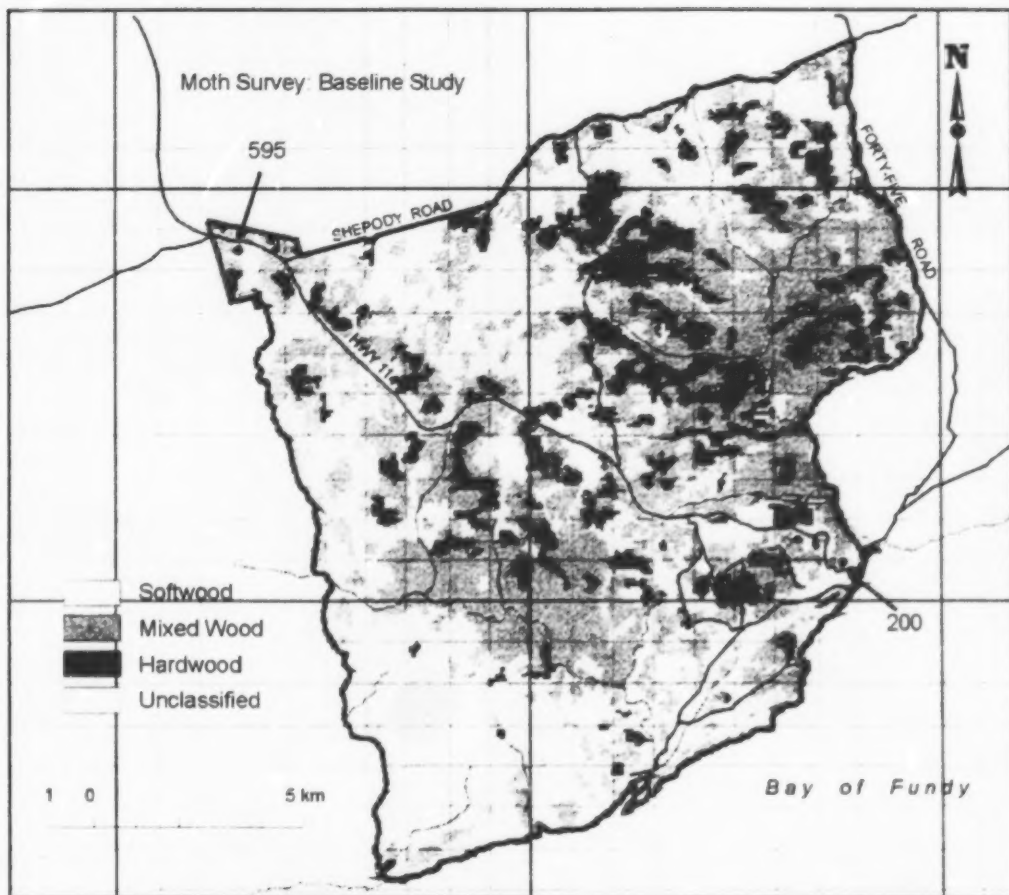
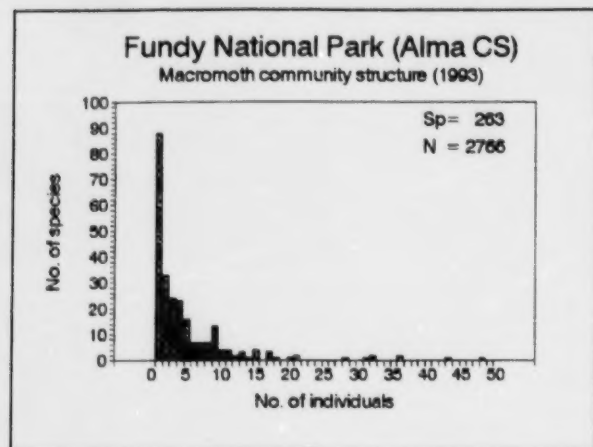
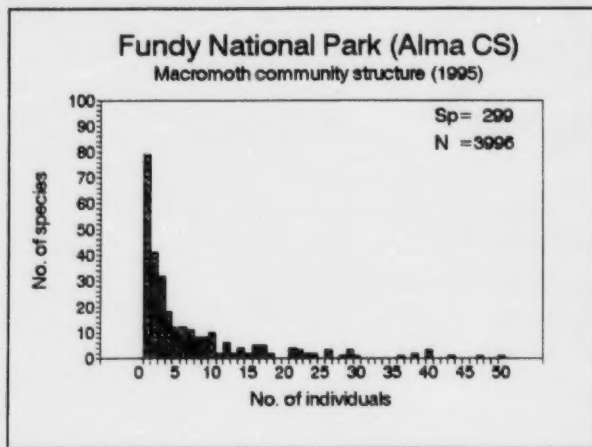


Figure 1. Long-term macromoth monitoring sites in Fundy National Park, Alma, New Brunswick. The shaded background represents a simplified forest classification scheme. The number 200 is the site of the Alma climate station, 595 is the Wolfe Lake climate station, the light traps were located adjacent to the climate monitoring sites.

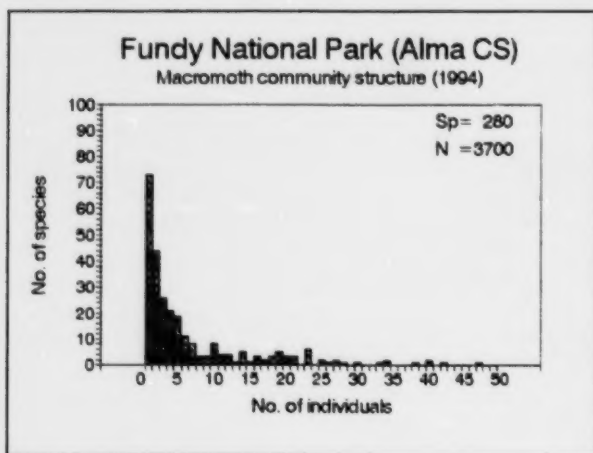
Diversity of natural habitats



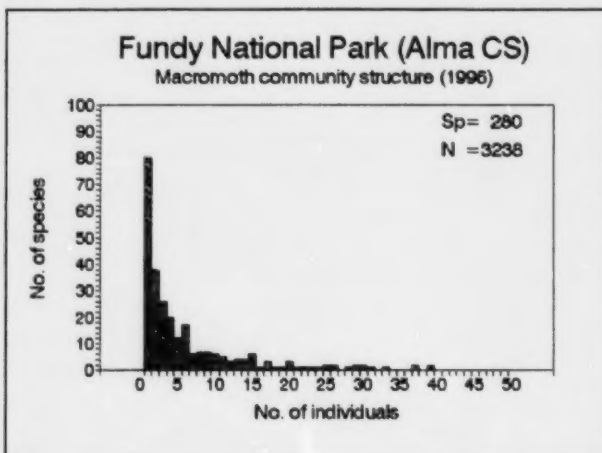
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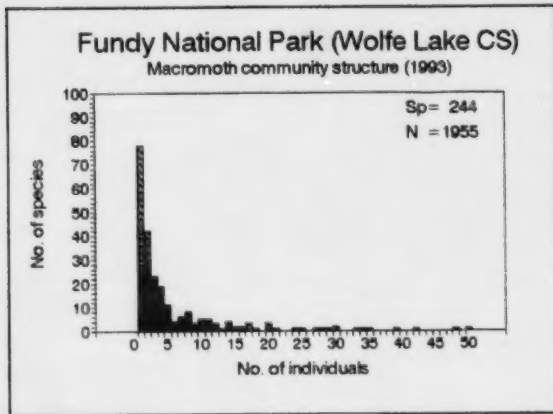
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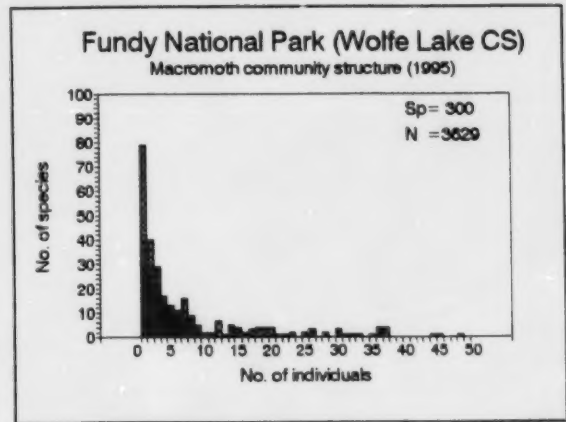
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Figure 2. Species abundance curves describing the macromoth community sampled by the Alma trap for 1993 to 1996.

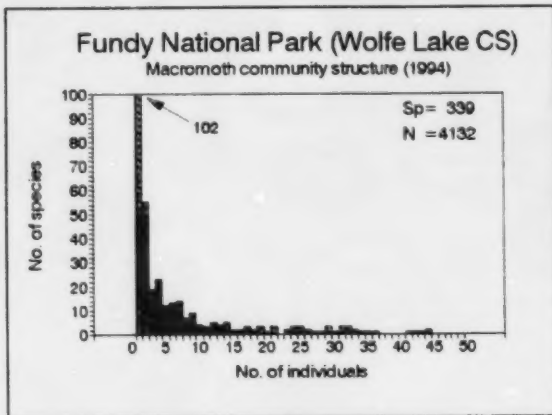
Diversity of natural habitats



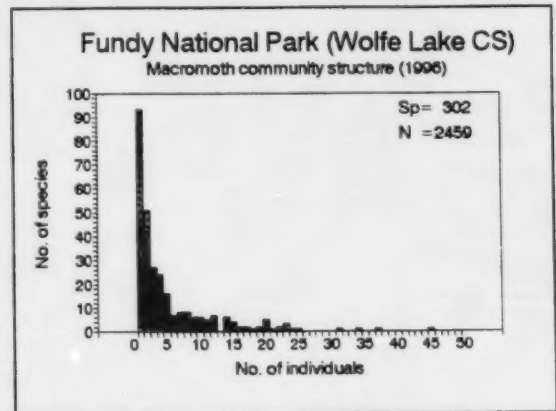
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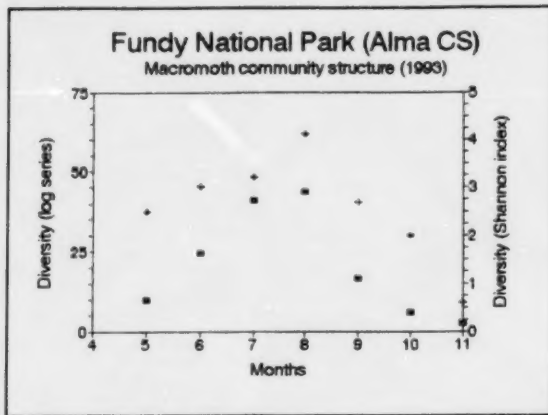
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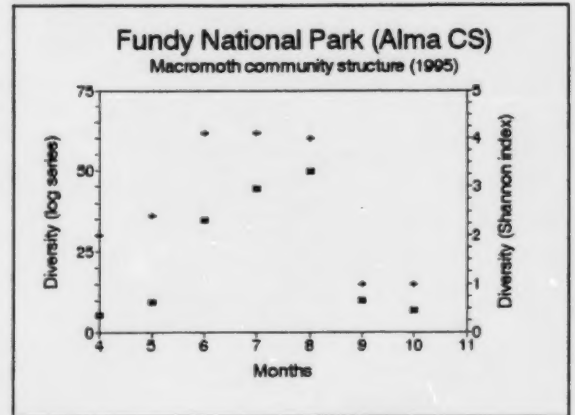
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Figure 3. Species abundance curves describing the macromoth community sampled by the Wolfe Lake trap for 1993 to 1996.

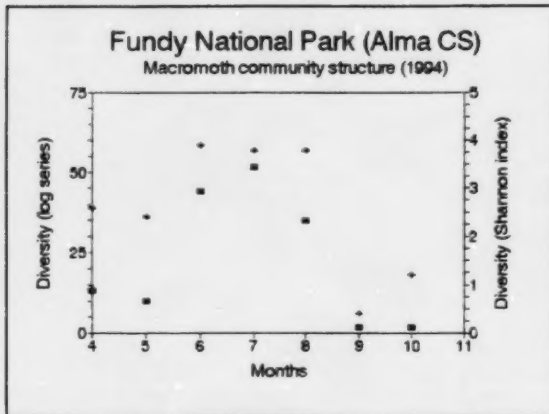
Diversity of natural habitats



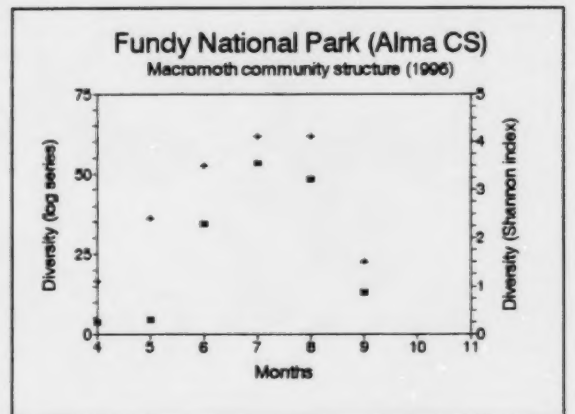
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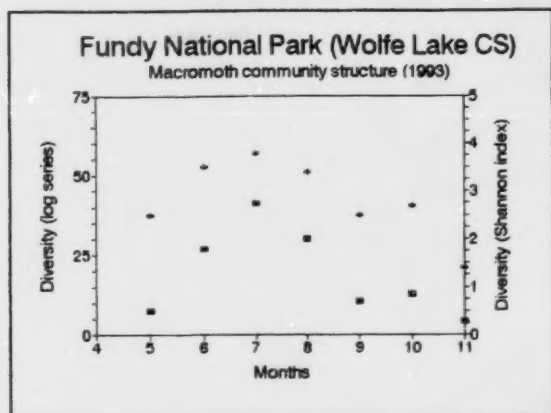
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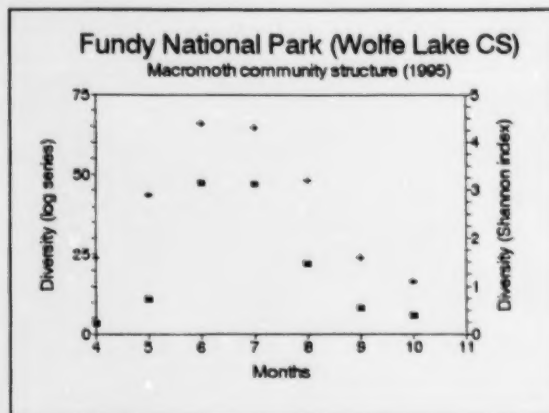
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Figure 4. Monthly macromoth community biodiversity at the Alma trap for 1993 - 1996. The plus sign represents the Shannon index and the solid box the log-series α index.

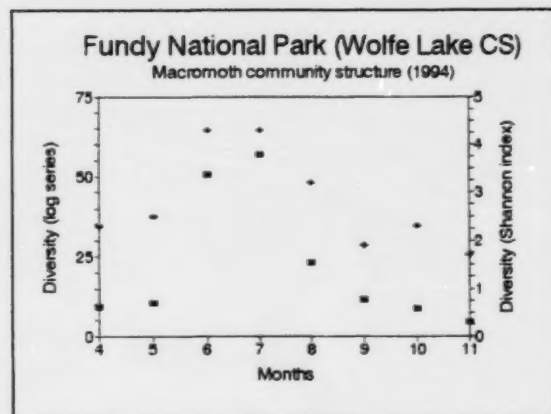
Diversity of natural habitats



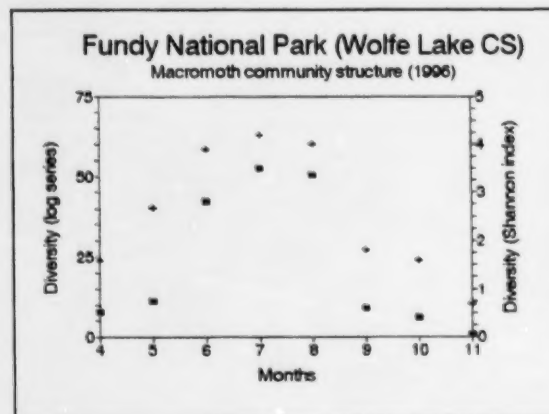
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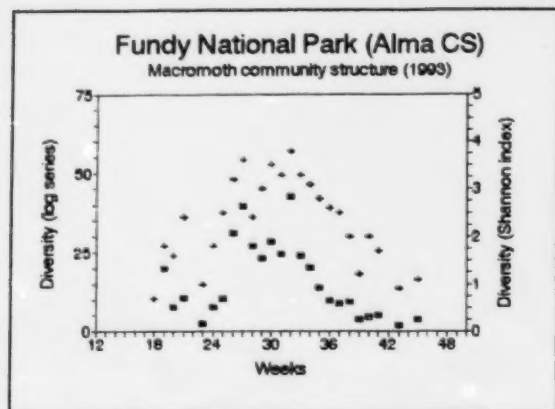
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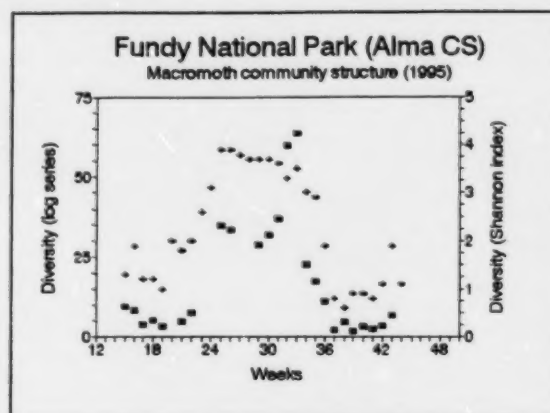
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Figure 5. Monthly macromoth community biodiversity at the Wolfe Lake trap for 1993 - 1996. The plus sign represents the Shannon index and the solid box the log-series α index.

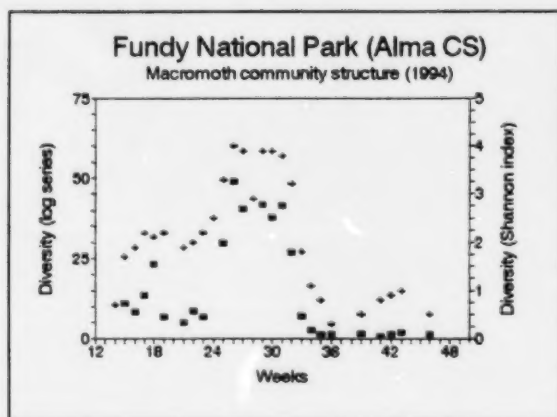
Diversity of natural habitats



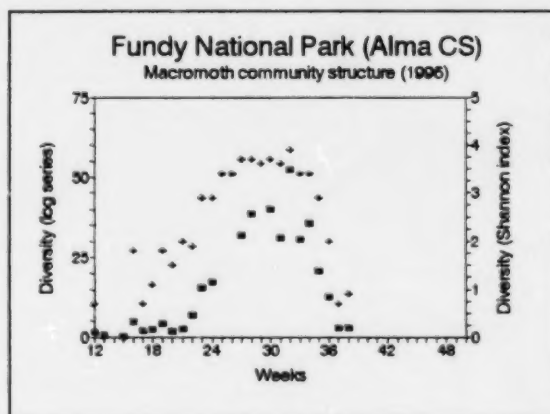
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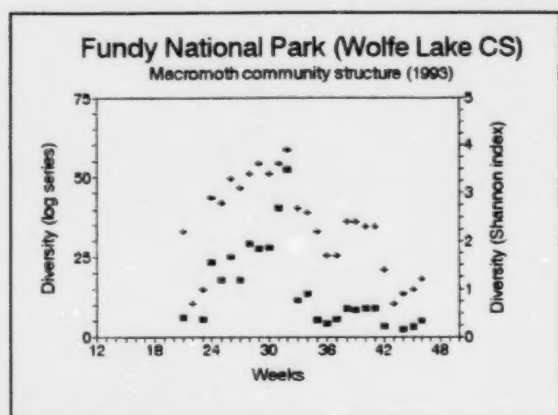
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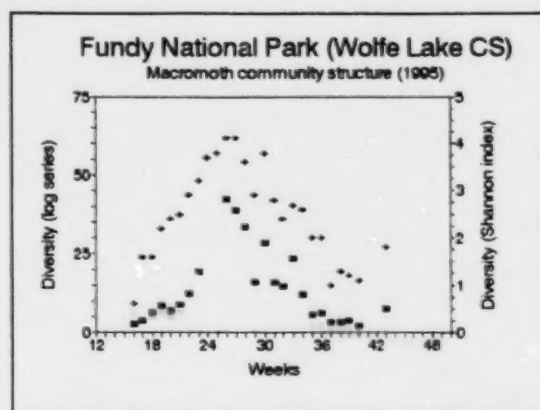
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Figure 6. Weekly macromoth community biodiversity at the Alma trap for 1993 - 1996. The plus sign represents the Shannon index and the solid box the log-series α index.

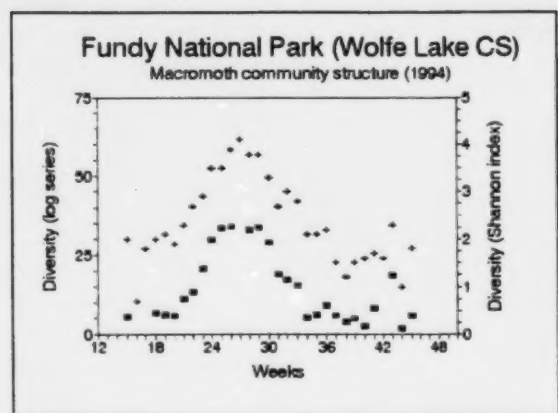
Diversity of natural habitats



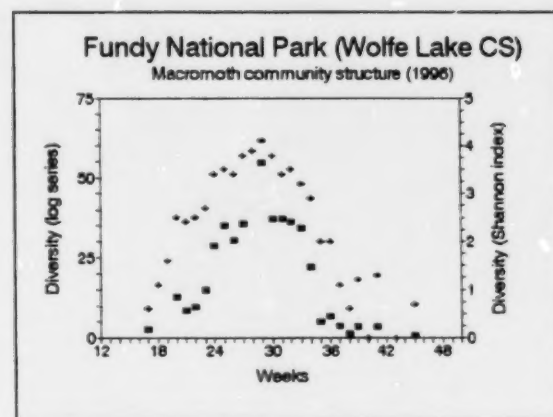
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Figure 7. Weekly macromoth community biodiversity at the Wolfe Lake trap for 1993 - 1996. The plus sign represents the Shannon index and the solid box the log-series α index.



Parcs Canada, région de l'Atlantique, produira trois séries de rapports en sciences des écosystèmes afin de communiquer de nouvelles données scientifiques, de consigner des données scientifiques, et de résumer les connaissances existantes ou de formuler des recommandations d'ordre technique. La fonction principale et le public visé détermineront la série dans laquelle un rapport sera publié. Chaque série contiendra des informations scientifiques et techniques qui viendront enrichir les connaissances existantes, mais ne pourraient être publiées dans les revues professionnelles en raison de leur présentation.

- **Les Rapports techniques en sciences des écosystèmes - Parcs Canada** favoriseront la diffusion à grande échelle d'information scientifique et technique tirée des études spéciales effectuées par Parcs Canada. La matière traitée et la série reflètent l'intérêt et les politiques de Parcs Canada dans de nombreux aspects des sciences des écosystèmes. La série comprendra des inventaires d'écosystèmes, des inventaires de ressources, des études diverses, des relevées sur des espèces ou des guildes et des concepts innovateurs de gestion.
- **Les Rapports d'études en matière de sciences des écosystèmes - Parcs Canada** permettront la publication de comptes rendus, de bibliographies et d'études d'options en matière de gestion faites par Parcs Canada. Les descriptions et les analyses de ressources sont aussi publiées dans cette série, en entier ou en partie.
- **Les Rapports de surveillance et de données relatives aux écosystèmes - Parcs Canada** offriront un moyen de présenter des compilations de données sans analyse détaillée. En général, ce genre de compilation sert à appuyer des publications scientifiques ou des rapports techniques en sciences des écosystèmes. Parcs Canada publiera dans cette série des données brutes qui ne sont pas incluses dans une banque de données nationale et qui méritent l'archivage.

Rapports en sciences des écosystèmes sont publiés dans la langue officielle choisie par l'auteur en fonction du public visé, avec un résumé dans la deuxième langue officielle.

Objectifs

Ces séries de rapports serviront à :

- communiquer les résultats des recherches effectuées en sciences des écosystèmes aux scientifiques et aux gestionnaires, ainsi qu'aux membres du public que les activités entreprises par Parcs Canada en écologie et en conservation intéressent.
- offrir des publications professionnelles, crédibles et précises qui seront soumises à l'évaluation par les pairs.
- favoriser la diffusion de l'information, la créativité, l'efficacité et le travail d'équipe dans les projets de recherche.

Évaluation par les pairs

Le rédacteur nommera deux lecteurs choisis, dans la mesure du possible, parmi le personnel scientifique de Parcs Canada, qui seront chargés de faire une critique de chaque manuscrit. On fera appel à des lecteurs de l'extérieur en raison de l'expertise exigée, du temps disponible et de l'objectivité nécessaire. Les lecteurs renverront le manuscrit au rédacteur en y joignant leurs commentaires par écrit. Le rédacteur renverra le manuscrit à son ou à ses auteurs avec les commentaires des lecteurs. L'auteur prendra connaissance des commentaires et tiendra compte de ceux avec lesquels il est d'accord, puis il retournera le manuscrit révisé au rédacteur en lui expliquant par écrit pourquoi il n'a pas tenu compte de certains commentaires. Le rédacteur enverra ensuite le manuscrit au garde de parc en chef, ou, s'il s'agit d'employés du bureau régional, au superviseur immédiat de l'auteur, pour faire approuver la publication et l'impression du manuscrit. Dans le cas de publications de moindre importance, le rédacteur peut, à sa discrétion, décider de ne pas avoir recours à des lecteurs; lui-même et le superviseur immédiat de l'auteur serviront alors de lecteurs. En cas de désaccord entre l'auteur et le rédacteur au sujet du manuscrit, c'est le gestionnaire ministériel principal qui tranchera.

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Ces séries de rapports seront consacrées à la publication de travaux effectués dans la région de l'Atlantique en science des écosystèmes et seront mises à la disposition de tous les employés de Parcs Canada, du ministère du Patrimoine canadien, de leurs collaborateurs ou de toute personne qui travaille pour le compte de Patrimoine canadien.

Les auteurs soumettront au rédacteur régional une copie de leur manuscrit sur support en papier, une version sur disquette en WordPerfect Windows ou DOS et le nom de trois lecteurs éventuels qui ne connaissent pas le manuscrit.

Pour de plus amples renseignements, communiquez avec :

Neil Munro
Rédacteur des séries de Rapports
Parcs Canada
Historic Properties
Halifax (Nouvelle-Écosse)
B3J 1S9
(902) 426-2797
FAX 426-2728